

Draft Natural Groundwater Remediation Work Plan
Ciba Specialty Chemicals Corporation
Former CPS Site, Old Bridge, New Jersey

November 4, 1999

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1 INTRODUCTION

This Draft Natural Remediation Work Plan outlines work to meet the requirements pursuant to the Technical Requirements for Site Remediation (N.J.A.C. 7:26E) regarding natural remediation of groundwater contaminated with organic compounds associated with the former CPS site at Old Bridge, New Jersey. The requirements apply to any portion of groundwater contaminant plumes that are not contained or otherwise not actively managed. The purpose of the requirements is to ensure that potential receptors are protected. In this case, the receptors of interest are the Perth Amboy water supply wells in the Runyon Wellfield. This work plan ensures that groundwater that does not meet NJGWQ standards will not impact the Perth Amboy water supply wells. Indeed, the plume associated with the former CPS site has been shrinking over the last several years.

This work plan is presented at this time to support the shut down of RW-2, per approval granted by RIDEM on August 18, 1999. Improvements in capture of contaminated groundwater in the vicinity of the source and the observation that groundwater quality has improved such that groundwater in RW-2 has met NJGWQS during the most recent three (3) quarterly sampling events support this decision. Capture of the source at the former CPS facility has been achieved by pumping wells WE-2R and CPS-3.

2 PURPOSE AND OBJECTIVES

The purpose of this work plan is to demonstrate and confirm that natural remediation processes, as applied to any uncaptured portion of the groundwater contaminant plume associated with the former CPS site, are protective of the groundwater in the Perth Amboy water supply. Specific objectives are:

1. through the use of a groundwater model, verify whether there is a potential for impacting the Perth Amboy groundwater supply wells by not continuing capture of the portion of the plume downgradient of the Madison property;
2. collect and interpret relevant groundwater quality data to determine whether natural attenuation processes, especially intrinsic bioremediation, are occurring within the plume;
3. monitor the plume to validate model predictions and
4. monitor the plume to ensure that groundwater quality does not deteriorate, according to the requirements of N.J.A.C. 7:26E.

3 ORGANIZATION OF WORK PLAN

Section 2 above provides the purpose and objectives for the work plan. Section 4 below summarizes site background information. Section 5 presents the rationale for considering natural remediation of groundwater for any uncaptured portion of the plume associated with the site. Section 6 identifies the project personnel and provides the contact information. Section 7 describes the scope-of-work, including identification of monitoring locations, identification of analytes and analytical methods, aspects of groundwater modeling and data analysis and reporting. Section 8 presents the schedule for the project.

4 SITE BACKGROUND

4.1 Site Location and Description

The former CPS site is located on Old Water Works Road in Old Bridge Township, Middlesex County, New Jersey (Drawing 1). The site is bounded by Old Water Works Road to the west and north, undeveloped land to the south and east and Madison Industries (Madison) to the west. Several industrial operations are found to the north and west; the Evor Phillips Superfund site is located approximately 200 feet north of the former CPS site. The Runyon municipal supply well field (Runyon Well Field) lies south-southwest of the former CPS site.

The entire former CPS property occupies 35 acres. In 1968 the process facility, which covers approximately 1.5 acres was constructed. At that time, reinforced concrete pads were built to support individual process vessels and storage tanks. Operation began between the end of 1968 and the beginning of 1969. The process and traffic areas now occupy approximately 4.5 acres.

All storage tank farms have been lined with reinforced concrete and contained by diked walls since 1975. Piping and storage tanks are located above ground surface. In 1978-1979, the entire 4.5 acres were graded and covered with concrete, soil cement and asphalt overlay to help prevent infiltration from accidental spills and stormwater into the subsurface soils. A containment curb surrounds the entire processing plant work and traffic areas. The ground surface has been paved and sloped to a central drainage swale and sump system, which discharge to the sanitary sewer.

4.2 Natural Setting

The regional topography around the former CPS site is relatively flat with little natural relief. The land surface elevation is approximately 25 feet above mean sea level (ft-msl). Local topography slopes gently to the south and southwest, towards Pricketts and Tennent Ponds (Figure 1).

Soils in the vicinity of the former CPS site are part of the Galestown Series, a somewhat excessively-drained soil of relatively coarse- to very fine-grained sands, formed on deep, loose, sandy sediments. In some locations, the sandy mantle is thick, but in others it is thin to nearly nonexistent.

During precipitation events, infiltration is quickly recharged to ground water. Vegetation is sparse, soils are permeable, and the ground surface is relatively flat in areas surrounding the former CPS facility. Excess surface water discharges to Pricketts Brook, a tributary of the Tennent Brook, which eventually discharges to the South River. In 1972, Pricketts Brook was diverted from transecting the former CPS site through construction of an artificial stream channel around the CPS facility's southern property line. Pricketts Brook, which is normally dry, flows intermittently to the southwest and discharges at the northeastern end of Pricketts Pond, which was built to retain surface water runoff and recharge the local aquifer (Figure 2).

4.3 Hydrogeologic Conditions

4.3.1 Geology

The former CPS site lies in the northeastern part of the Coastal Plain Physiographic Province, which consists of a large, regional wedge of unconsolidated and poorly-consolidated sands, gravels, silts and clays. The thickness of this sediment wedge and the depth to bedrock increase to the southeast. According to Zapecza (1984), the depth to the top of bedrock near the former CPS site is approximately 270 to 300 ft-bgs.

At the former CPS site, the Old Bridge Sand, a member of the Cretaceous-age Raritan Formation, occurs from just below ground surface to approximately 55 ft-bgs. The Old Bridge Sand is primarily a fine- to coarse-grained, well-sorted sand with occasional, discontinuous, thin beds of clay. Locally, a veneer of the Quaternary-age Cape May Formation overlies the Old Bridge Sand. The two units are lithologically similar and are in direct hydraulic connection.

The Old Bridge Sand is underlain by the South Amboy Fire Clay. Where present, the South Amboy Fire Clay is found at a depth varying from 55 to 85 ft-bgs. Wehran Engineering (1986) found the clay to be thin or absent beneath portions of the former CPS and Madison sites. Underlying the South Amboy Fire Clay is a thin layer of the Sayreville Sand, which has a composition similar to the Old Bridge Sand. The laterally continuous Woodbridge Clay with an average thickness of about 100 feet lies beneath the Sayreville Sand and is the confining unit between the Old Bridge Sand and Farrington Sand aquifers. The underlying Farrington Sand is a fine- to medium-grained unit of variable thickness.

A hydrogeologic cross-section of the "shallow and intermediate zones" beneath the CPS site is provided as Figure 5. The geologic information was compiled from the soil boring/hydropunch data and logs for CPS monitoring wells (Appendix A of the 1996 DRAI Phase II RI Report).

4.3.2 Hydrogeology

The Cape May, Old Bridge and Sayreville Sand units comprise the Old Bridge water-table aquifer at the former CPS facility and the Runyon Well Field. The South Amboy Fire Clay is a confining unit existing within the Old Bridge aquifer, but is not laterally continuous. The Woodbridge Clay, a continuous confining unit with a thickness of about 100 feet, separates the Old Bridge Sand and Farrington Sand aquifers. The Farrington Sand is a major regional aquifer.

Based on local aquifer pumping tests (Roy F. Weston, 1992; Wehran, 1990; Pucci et al., 1989), the average hydraulic conductivity (K) of the Old Bridge aquifer in the vicinity of the former CPS site ranges from approximately 74 to 100 feet/day, and the effective porosity is approximately 40 percent (Barksdale, 1943 and Hasan, et. al. 1969). Storativity values range from 0.02 to 0.05, which are typical for unconfined aquifers containing clay layers.

Ground water levels are shallow, encountered from approximately 6 to 10 ft-bgs in monitoring wells located on and downgradient of the former CPS site. Water level fluctuations are coincident with precipitation events due to the permeable recharge characteristics of the ground surface.

Ground water elevation contours indicate a southwest flow direction under both static and pumping conditions. The hydraulic gradient of the water table appears to be consistent and relatively flat at an average value of 0.004 foot/foot. Water table levels measured adjacent to Pricketts Pond indicate that ground water from the north discharges into the pond; to the south the pond appears to recharge the aquifer.

4.4 Site History

4.4.1 Current and Historical Operations

In 1969, CPS commenced operations at the Old Bridge site with the production of chemicals and the recovery of valuable materials from process by-products or residuals. In 1974, CPS began producing monomers, which are intermediates for the production of water-treatment chemicals. These intermediates are converted into polymers that aid in the coagulation and flocculation of suspended solids.

Presently owned by the Ciba Specialty Chemicals Corporation, the former CPS facility at Old Bridge primarily produces chemicals for the water-treatment industry, but continues to refine and recover methanol, glycols and other solvents. The chemical manufacturing and refining are conducted in open-sided structures. Water is obtained from the municipal water supply system and two on-site production wells (PW-1 and PW-2), which are located in the vicinity of the main processing area. Wells PW-1 and PW-2 are both screened in the Old Bridge Sand at approximately 60 feet below ground surface (ft-bgs). The total production well yield is about 50,000 gallons per day (gpd).

4.4.2 Regional Ground Water Use and Conditions

The City of Perth Amboy operates the Runyon Well Field, located approximately 3,000 feet south-southwest of the CPS facility (Figure 2). Current withdrawal is from four wells; each screened in the Old Bridge Sand at depths ranging from 55 to 77 ft-bgs. Individual well yields range from 500 to 1,000 gallons per minute (gpm), and total pumpage is approximately 5 million gallons per day (MGD).

Both Pricketts and Tennent Ponds were created to enhance ground water recharge to the Perth Amboy supply wells. In the 1920s, a dam was constructed on Tennent Brook, creating Tennent Pond. In 1972, a second dam was constructed across Pricketts Brook, creating Pricketts Pond (Figure 2).

4.4.3 Historical Ground Water Contamination and Remediation in Perth Amboy Well Field

In the early 1970s, the Bennet Suction Line served as a potable water source for the City of Perth Amboy. This line of approximately 30 shallow wells connected by a common manifold was located southwest of the former CPS and Madison sites. Individual well depths ranged between 35 and 55 ft-bgs.

In 1971 and 1973, metals were detected in the Bennet Suction Line wells. In March 1971, suction line wells Nos. 1 through 6 were abandoned. In March 1973, Perth Amboy discontinued use of the remaining wells. To replace potable water once supplied by the suction line, supply wells of approximately 55 to 77 feet in depth were installed north of Tennent Pond.

In October 1981, a groundwater remediation program was ordered by the court. In response, CPS and Madison developed an alternative remediation program which included; (1) installation and operation of a ground water recovery system; (2) relocation of Pricketts Brook to a position south of the former CPS property line; (3) discharge of treated effluent via the Old Bridge Municipal Utilities Authority (OBMUA) line to the Middlesex County Utilities Authority (MCUA) treatment plant; and (4) installation of a performance monitoring program. The program was approved by the NJDEP and submitted to the court in 1985.

Monitoring wells were installed between the former CPS/Madison sites and the supply wells in the late 1980s. From approximately 1984 to the present, certain volatile organic compounds (VOCs) have been detected in monitoring wells downgradient of the former CPS and Madison sites as well as in upgradient wells.

On January 25, 1991, ground water pumping began at four recovery wells (RW-1, RW-2, RW-3 and RW-4) located downgradient of the former CPS and Madison properties to remediate VOCs and metals contamination in the Old Bridge aquifer. Recovery wells RW-1 and RW-2 were installed by CPS, and wells RW-3 and RW-4 were installed by Madison (Figure 2). The individual pumping rates at the recovery wells ranged from about 50 to 200 gpm. The greatest discharge rate of approximately 200 gpm was recovered from well RW-2.

In August 1992, a fifth recovery well (RW-5) was completed by CPS 550-feet upgradient of supply well PA-6 to recover ground water with low chlorobenzene concentrations downgradient of recovery well RW-2. As of April 1993, four of these five recovery wells were in operation. Madison has since installed an additional recovery well (RW-6) for control of metals contamination in ground water. Subsequently, RW-3 was removed from service in favor of an increased pumping rate at RW-6.

As a result of the operation of recovery wells RW-2 and RW-5 and an overall decline of VOC concentrations, detected chlorobenzene levels at well PA-6 have been below 1.0 ppb since April 1993 (DRAI, June 1995). In June 1995, CPS petitioned the NJDEP to terminate operation of recovery well RW-5 due to the decreasing contaminant concentrations in the Runyon Well Field. The request was granted in July 1995.

During December 1996, Madison installed four shallow recovery wells (RS-1A through RS-1D) to enhance recovery of metals contaminated groundwater. The shallow recovery system was placed into service in February 1997. RW-6 was removed from service at that time. Recovery well RW-4 was removed from service in May 1997. During June 1998, a second shallow recovery system (RS-2A through RS-2C) was installed adjacent to RW-4. The system became operational in November 1998.

Recovery operations on the former CPS site commenced in March 1996 to remediate groundwater contamination near the source of VOCs contamination. Two recovery wells, WE-2R and CPS-3, are used for this purpose. Pumping rates in these wells have collectively averaged 20 gallons per minute until they were increased to 25 to 30 gpm in February 1999. The rates were increased to expand the capture zone in the vicinity of the source area.

Extracted groundwater is treated in an air stripper and vapor phase carbon prior to being discharged into a groundwater recharge basin.

Monitoring data collected since 1996 continues to indicate improvement in overall groundwater quality and a shrinking plume. In the four (4) most recent reported sample events, there have been only three (3) instances of exceedances of NJ GWQS downgradient of RW-2, all of which were qualified as J-values and all of which were reported in a single well, EPA-5. J-qualified data refer to estimated concentrations below the method detection limit, so that the actual concentrations in these instances may have been below the NJ GWQS. These improvements in groundwater quality are detailed in Section 5. Because of these continued improvements in groundwater quality in the plume and the observation that concentrations exceeding GWQS were now located upgradient of RW-2, Ciba petitioned NJDEP to terminate operation of RW-2. Also in support of the petition, improvements have been made to the on-site capture systems at both the former CPS facility and Madison, so that source capture and control of the upgradient portion of the plume has been enhanced. Pumping rates were increased from 20 gpm to 25 to 30 gpm at the former CPS site in February 1999. Further, in November 1998, three (3) pumping wells on the Madison property, RS1A through RS1C, were turned on, further enhancing capture upgradient of RW-2. In a letter dated August 18, 1999, NJDEP approved the petition to terminate the operation of RW-2. The rationale for the termination of pumping in RW-2 is described in detail in Section 5.

4.5 Nature and Extent of Groundwater Contamination

The nature and extent of groundwater contamination have been described in detail in the Phase I and Phase II RI reports (DRAI 1994; 1996). Groundwater contamination is also described in the quarterly groundwater monitoring reports. Since the Phase I and Phase II RIs, groundwater quality has improved, as described in the following subsections. This section provides a summary of impacts to ground water quality.

4.5.1 Groundwater contamination on the former CPS site

Ground water samples were collected from eight existing monitoring wells during the Phase I RI and ten monitoring wells during the Phase II RI for VOCs+15 and PP Metals analyses. Wells WE-2, WE-2R, CPS-1 and CPS-3 contained significant VOC levels, with some concentrations 1 to 3 orders of magnitude above the NJDEP Class IIa ground water quality standards (Class IIa standards). These parameters included acetone, benzene, chlorobenzene, 1,2-dichlorobenzene, 1,3-dichlorobenzene, 1,4-dichlorobenzene, 1,2-dichloroethane, trans-1,2-dichloroethylene, methylene chloride, toluene, 1,1,2-trichloroethane, 1,1,2,2-tetrachloroethane, trichloroethylene, vinyl chloride and total xylenes.

The ground water component of the Phase II RI included the use of the hydropunch sampling method to delineate the elevated VOC levels observed in well WE-2. The results of the hydropunch sampling revealed a hotspot of VOC contaminants within the main process area, specifically, beneath Tank farms 1 through 5. Vertical delineation showed the VOC contamination limited to a depth interval extending from the water table to approximately 40 ft-bgs (Figure 5).

Methylene chloride, 1,2-dichloroethylene (total), 1,2-dichloroethane and trichloroethylene were detected in samples collected from an upgradient well (WCC-1M), indicating an off-site source. These four compounds were also detected in several on-site wells and were found at the highest concentrations in well WE-2 (individual VOC levels ranging from 14,400 to 27,550 ppb). It is likely that the total VOC concentrations detected in well WE-2 result from both upgradient and on-site source contributions.

Based on the RI data, elevated VOC concentrations appear to be largely limited to the tank farm area of the former CPS site. Hydropunch and ground water sampling have delineated the contaminant hotspot to Tank Farms 1 through 5. The width of the hotspot (west to east) is less than 140 feet, based on the "clean" conditions detected at wells WCC-5s and WCC-6s. The vertical distribution of contaminant compounds is based primarily on hydropunch sampling data. In general, total VOC concentrations were highest at the water table and decreased with depth. The maximum vertical extent of the hotspot is approximately 40 ft-bgs.

Note that, based on Table 1 below, the groundwater quality in the hotspot recovery wells, WE-2R and CPS-3, have declined significantly since the preparation of both Phase I and Phase II of the RI. Overall, concentrations of total VOCs in WE-2R have declined from approximately 59,000 µg/L in 1994 to under 3,000 µg/L in 1998. CPS-3, a source area recovery well, has declined in total VOC concentration from approximately 9,600 µg/L in 1996 to approximately half that value, 4,800 µg/L in 1998. This monitoring data suggests strongly that the mass flux from the source area to the aquifer has declined markedly since the RI Phase I and Phase II were completed, indicating that the source has been attenuating.

4.5.2 Delineation of Ground Water Contamination Downgradient of the CPS Facility

The VOC contaminant hotspot at the former CPS tank farm area is identified as a source for the downgradient VOC plume. Presently, contaminant levels exceeding NJ GWQS extend from the hotspot to monitoring well WCC-16VS, which is approximately 1,400 feet downgradient (Drawing 3). Separated in space from this plume is EPA-5, in which exceedances at low concentrations have been detected. This monitor well is located approximately 700 feet downgradient of WCC-16VS and approximately 1,000 feet upgradient of water supply well PA-6. RW-2, located between the plume and EPA-5, has shown no exceedances of GWQS in the most recent three (3) reported quarterly monitoring events. The width of the contaminant plume generally varies between 300 and 400 feet.

The extent and shape of the downgradient contaminant plume is consistent with the general ground water flow direction at the former CPS site and the Runyon Well Field property (Drawing 2). Ground water leaving the former CPS site flows southwest. From the vicinity of RW-2, ground water flows southerly toward the Perth Amboy supply wells.

Vertical plume migration is controlled by a discontinuous clay unit (South Amboy Clay) as well as by pumping of water supply wells. The clay unit is located at an approximate depth interval of 45 ft-bgs. The clay unit is absent south of recovery well RW-2, allowing vertical migration of contaminants to the downgradient monitoring wells. The supply wells, located downgradient of these latter monitoring wells, are screened at an approximate depth interval of 65 to 85 feet, creating a downward vertical gradient.

The VOC compounds found downgradient of the CPS/Madison site are similar to the suite of compounds found at the former CPS facility source area but are generally detected at lower concentrations. The number of VOC compounds exceeding the NJDEP Class IIa standards downgradient of the site is reduced to 3 from a total of 12 compounds that exceed NJ GWQS at the source area. A summary of the current VOC exceedances found in the plume is provided in Drawing 3. Since 1991, the contaminant concentrations in and the size of the plume have decreased as a result of the operation of the recovery wells and natural attenuation processes, as discussed in the following section.

5 RATIONALE FOR NATURAL REMEDIATION OF GROUNDWATER

The rationale for proposing the natural remediation of any uncaptured portion of the groundwater plume was presented in Ciba's proposal to allow the termination of pumping of RW-2. In the proposal, the rationale for the discontinuation of pumping of RW-2 was based on:

- 1) the groundwater monitoring data of the last several years that indicates improved groundwater quality in the part of the plume downgradient of RW-2 (Table 1),
- 2) the lack of exceedances of NJ GWQS downgradient of RW-2 during the most recent two (now three) sampling events,
- 3) the long travel times for groundwater between RW-2 and the most directly downgradient Perth-Amboy water supply well, and
- 4) improvements (higher pumping rate on the former CPS site, new wells on Madison site) made to the on-site capture system(s), further enhancing capture of groundwater near the source,

Ciba is confident that the proposed program to shut RW-2 down with monitoring and the appropriate documentation of natural groundwater remediation, per N.J.A.C. 7:26-E and this work plan, is protective of the groundwater supply.

Table 1 below, which summarizes data collected in the plume since 1993, illustrates this first point. Detailed data from which Table 1 was derived is found in the most recent quarterly PMP report (EMCON, 1999). The wells on the table are located within and directly downgradient of the plume, more or less along its axis. On the table, the most upgradient wells are listed first, with the wells furthest downgradient listed at the bottom. Wells CPS-3 and WE-02R are located on the former CPS facility, near the source area. Well distances from the source area range from approximately 100 feet for CPS-1 to approximately 3,000 feet downgradient from the source in the case of EPA-2 (Drawings 2 and 3).

A feature of the plume that is apparent from an examination of the table is that concentrations tend to decline the further from the source the well is located, as expected. Local variations of this trend are attributed primarily to the relative locations of wells relative to the plume axis. That is, wells located nearer to the lateral edge of the plume are expected to have lower concentrations than those located nearer to its axis. The local pumping history plume also has impacted the distribution of contaminants within the plume.

Another feature of the plume is illustrated by the observation that concentrations in seven (7) of the sixteen (16) wells have declined markedly since 1996. In the remaining wells, concentrations do not appear to have changed very much since 1996. This data supports the contention that the plume is shrinking, with some variations due to seasonal effects or changes in pumping regime, among other factors.

Table 1. Summary of Plume Groundwater Quality versus Time, TVOC

Well Number	1993	1994	1995	1996	1997	1998	Dec. 1998	Mar. 1999	June 1999
	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)
CPS-3	NA	NA	2,389	9,646	5,863	4,840	5,312	4,201	4,466
WE-02R	NA	59,010	41,758	13,416	5,024	2,957	2,271	1,461	1,916
CPS-1	NA	NA	12,253	4,526	4,674	2,789	230	375	148
PA-B	110	120	532	138	249	164	380	33	34
DEP-2	182	126	84	86	48	80	37	82	12
DW-5S	1,013	19	32	8	7	2	5*	13*	6*
DW-5D	15	ND	20	9	9	0.3	ND*	ND*	0.7*
WCC-16VS	16	331	24	83	302	76	98	138	78
RW-2	556	283	524	268	65	30	29*	26*	22*
EPA-5	321	202	58	45	34	53	52	10*	27
DW-13D	3	2	3	6	68	13	8*	7 ^a *	2*
DW-14	7	4	5	6	7	6	2*	2*	7*
EPA-1	12	6	3	17	23	5	3*	12*	6.5*
DW-9D	0.2	ND	ND	0.4	0.7	5	ND ^a *	ND*	0.6*
DW-9S	3	0.2	0.2	1	0.5	0.8	ND*	ND*	0.8*
EPA-2	21	8	5	2.5	1	1	ND*	ND*	2*

* = No exceedances of NJ GWQS (applies to last three columns only)

NA = Not analyzed

ND = Not detected

Note: The first six columns of data are concentration averages of the quarterly sampling rounds that occurred in each year. The last three columns contain data for each of the most recent three reported quarterly sampling events.

Note: Acetone omitted from totals. Not included (analyzed) in early data. Also frequently found in blanks.

The generally low total concentrations indicated in the downgradient wells are largely due to reported values below the method detection limit (MDL), qualified in data laboratory deliverables as J values. For example, all of the detected values for the most recent sample event downgradient of EPA-5 (bottom six (6) rows of Table 1) are J values. Also note that the two wells that have exceedances of NJGWQ standards below DEP-2 (bottom eleven (11) rows on Table 1) since December 1998 were also qualified as J values.

The second point of the rationale for natural groundwater remediation is supported by the observation that only one well downgradient of RW-2 has had exceedances of NJGWQ standards in the last three quarterly monitoring rounds. In this well, EPA-5, the exceedances in two of the last three monitoring rounds were for J qualified values. These are relatively low concentrations in a well located approximately 1,200 feet upgradient from the most directly

downgradient municipal water supply well, PA-6, and in which concentrations have been relatively steady since 1995. This well also lies outside the former RW-2 capture zone (Drawing 2). Concentrations of VOCs in wells downgradient of EPA-5 have remained below NJGWQ standards since at least June 1998. This data supports arguments made in 1995 for allowing the cessation of pumping in 1995 in a report titled Assessment of the Need for Continued Operation of Well RW-5 as Part of the Ground Water Recovery Program (DRAI, 1995), which included groundwater transport modeling.

The third point of the natural groundwater remediation rationale is supported by the observation that RW-2 is located approximately 1,600 feet upgradient of PA-6, which is on the order of four (4) to six (6) years travel time from that well. The implication here is that there is a relatively large distance and time for natural attenuation processes to operate and also a significant opportunity to detect any concentrations that pose a potential risk to the water supply with the monitoring well network currently in place.

The fourth point, improved capture in the upgradient portion of the plume near the source, ensures that additional mass flux to the downgradient portion of the plume has been controlled. Such decreased or eliminated contaminant flux results in further plume attenuation than that which would otherwise occur, which should be demonstrated as a result of implementation of this work plan.

6 PROJECT PERSONNEL

Project personnel and areas of responsibility are as follows. Oversight from NJDEP for this project will be provided by Paul Harvey, who is the case manager for the overall site remediation project. The project manager for Ciba is Dan Pardieck. The responsibilities of the project manager are to coordinate field and laboratory activities, maintain appropriate communications with project and NJDEP personnel and reporting. Fieldwork will be performed by EMCON/IT, with Steven Goldberg being the primary contact. EMCON/IT currently conducts the performance monitoring program (PMP) for the site. The contact for the facility is Tom Hoppe.

Relevant contact information is as follows:

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7 SCOPE OF WORK

To meet the objectives indicated in Section 2, three (3) tasks are included in this work plan, 1) monitoring of VOCs in groundwater in selected wells, 2) measurement of relevant geochemical parameters in selected monitoring wells to support the occurrence of naturally occurring biological processes and 3) groundwater transport modeling of selected VOC constituents. The completion of these tasks will conform to the technical requirements for the demonstration of natural groundwater remediation as indicated in N.J.A.C. 26E-6.3.

7.1 Groundwater Sampling and Analysis Program

7.1.1 Groundwater monitor wells

A total of thirteen locations have been selected for this project (Table 2). These include two (2) wells in the source area for the plume, an upgradient plume well, four wells (4) located near the plume axis at different distances from the source, two (2) plume fringe locations, three (3) sentinel locations and one well background to the site. All of these wells are currently part of the quarterly PMP.

Each of these locations will be sampled and analyzed for VOCs and geochemical parameters. Geochemical parameters refer to a list of parameters that are not a part of the normal PMP sampling program and which will be used as evidence to support the occurrence of natural attenuation processes such as biodegradation. Most geochemical parameters are inorganic analytes. Sampling for VOC analysis will occur during the PMP quarterly monitoring events using the usual sampling techniques, for a total of eight quarters. However, because of the desire to obtain VOC analytes additional to those currently measured and to obtain lower detection limits for most compounds, the analytical method used will be 524.2 with a modified list of analytes, as described below. Geochemical parameters will be sampled separately in the wells listed in Table 2, within two months following approval of the Groundwater Natural Remediation Work Plan, after one year and after two years. Low flow sampling techniques, as described below, will be used to obtain geochemical samples. The parameters and the reasons for their inclusion in the program are discussed in Section 7.1.3 below.

Table 2: Monitor locations for the Natural Groundwater Remediation Project, Former CPS Site

Well Number	Screened Interval (ft. bgs)	Analytical Parameters	Sampling Method	Rationale
CPS-3	20-40	VOCs, Geochemical	Slow purge	Source area
WE-02R	23.7-33.7	VOCs, Geochemical	Slow Purge	Source area
CPS-1	20-40	VOCs, Geochemical	Slow Purge	Upgradient part of plume
PA-B	?	VOCs, Geochemical	Slow Purge	Plume axis
DEP-2	24.5-36.5	VOCs, Geochemical	Slow purge	Plume axis
DW-5S	14-24	VOCs, Geochemical	Slow purge	Mid plume, near lateral fringe
WCC-16VS	9-19	VOCs, Geochemical	Slow purge	Plume axis
RW-2	24.7-44.7	VOCs, Geochemical	Slow Purge	Plume Axis
EPA-5	63-83	VOCs, Geochemical	Slow Purge	Downgradient fringe, Plume axis
DW-13D	50-65	VOCs, Geochemical	Slow purge	Sentinel well
DW-14	28-43	VOCs, Geochemical	Slow purge	Sentinel well
EPA-1	61-81	VOCs, Geochemical	Slow purge	Sentinel well
WCC-3M	38-48	VOCs, Geochemical	Slow purge	Background to site

? = The screened interval of PA-B was not available, though the reported total depth of the well is 44 ft.

7.1.2 Sampling methodology

The monitoring program in support of natural groundwater remediation is divided into two components. The first component is the analysis of VOCs. VOC sampling analysis in support of the natural groundwater remediation program will be conducted during the quarterly PMP sampling and analysis program. All of the wells selected for use in the natural groundwater remediation program are currently in the PMP program, so the VOC data will be used to support both programs. The procedures of sampling and analysis for the VOCs remain the same as they have for the PMP (Wehran Engineering, 1990a), except that, as indicated above, EPA method 524.2 will be used as a replacement method to measure additional compounds and to achieve a lower detection limit. This method will also become the preferred method for the PMP program, primarily because of the lower detection limits achieved. The other laboratory and additional field parameters, referred to as geochemical parameters, will be sampled three times over the course of the two year project, at the beginning, after one year and at the end of two years, and sampled using a low flow sampling protocol.

The VOCs sampling and analysis procedures are not described in detail in this work plan, as they are detailed in the 1990 Sampling and Analysis Plan. Procedures related to the low flow protocol for use in sampling for geochemical parameters are described below.

A slow purge sampling technique will be used for the collection of geochemical parameters in all of the wells included in natural groundwater remediation program. The rationale for this is that several of the geochemical parameters, such as dissolved oxygen (DO) or other redox sensitive species and dissolved gases, are sensitive to sampling disturbances. Slow purge techniques minimize such disturbances, ensuring the collection of samples representative of aquifer conditions in the vicinity of the monitoring location. The low-flow purging and sampling

procedure is essentially the standard method for low-flow sampling used by the USEPA (Appendix A), with minor modifications, as necessary.

For low flow purge and sampling, a QED Environmental Systems, Inc. Stainless Steel Bladder Pump and Bladder Controller will be used. A YSI 6820 flow through cell will be used to allow the measurement of field parameters during purging. The tubing will consist of Teflon bonded or polybonded tubing. General procedures for preparation, purging and sampling are described below.

7.1.2.1 Equipment Decontamination

Equipment associated with the tasks involved in groundwater sampling and field parameter measurements will be decontaminated prior to use in the field. All sampling equipment will also be decontaminated between sample locations unless dedicated sampling equipment is used.

Transportation of all equipment will be performed in a manner that eliminates the possibility of cross-contamination. Calibration fluids, fuel, decontamination water, and all other sources of contaminants will be segregated from sampling equipment during transport. Purge water being transported to holding or disposal areas will be kept in closed containers.

Decontamination procedures are summarized below.

- Decontamination of the dissolved oxygen, pH and redox and conductivity probes should be conducted carefully to minimize damage to sensitive probe membranes and to avoid introduction of decontamination water into the probe bodies. The probes will be rinsed with clean potable water and dried in between sampling locations.
- The flow-through cell will be rinsed with clean potable water in between locations. If contamination is apparent, then the flow-through cell will be dismantled and subjected to a more vigorous cleaning using phosphate-free laboratory soap and rinsing with clean water.
- The pumps will be decontaminated prior to use. Each decontaminated pump will be used only once and then subjected to decontamination procedures.

7.1.2.2 Field Instrument Calibration and Maintenance

All field measuring and analytical equipment will be properly maintained and calibrated. Field instruments will be calibrated and maintained according to manufacturer specifications, at a minimum.

Calibration will occur daily prior to use and at periodic intervals, as necessary. Calibration records that document the time, date, standards used, and other observations will be maintained for each instrument. Certified standards will be used, where applicable. Instruments that fail to meet calibration/checkout procedures will be repaired on site, if possible, or returned to the manufacturer for problems requiring more extensive service. Calibration and maintenance records for field measuring and analytical equipment will be stored in the project files.

7.1.2.3 Pre-purging and Purging Methods

For the purposes of this project, a low flow pump is recommended for purging and sampling for geochemical parameters. For this purpose a QED Environmental Systems, Inc. stainless steel bladder pump and bladder controller will be used. A brief summary of the purging procedures is presented below. Additional detail is found in Appendix A.

- Pre-purge preparations and measurements will be conducted as described in the Sampling and Analysis Plan for Groundwater Monitoring at the CPS Chemical/Madison Industries Site (Wehran Engineering, 1990a).
- A down hole, low flow pump will be used for purging.
- Field measurement of dissolved oxygen, temperature, pH conductivity, and redox potential will be conducted using a flow through cell (YSI 6820). The sample discharge tube extending from the pump will be connected to the in-line flow cell equipped with a calibrated dissolved oxygen, temperature, pH, redox potential, and specific conductance probes. (Note that, in standard purging and sampling procedures for the collection of VOCs samples, a flow through cell will not be used and the field parameters consist of temperature, pH and conductance.)
- Purging will commence immediately following installation of all equipment and recording of initial conditions. Dissolved oxygen, temperature, pH redox potential and specific conductance and time of their measurement will be monitored and noted as pumping proceeds.
- Purging will be considered complete when all parameters have stabilized as defined in Appendix A.

7.1.2.4 Sampling Method

Groundwater samples for field and laboratory analysis of geochemical parameters will be collected only after criteria for purge-stabilization have been met, per Appendix A. All samples for field and laboratory analysis will be collected from the sample line after the line has been disconnected from the in-line flow cell. The sampling pumping rate will be between 100 and 250 ml/min. The sample containers will be filled in a manner to minimize agitation or aeration of the sample.

7.1.2.5 Sample Containers, Preservatives, Holding Times

Sample volume requirements, preservation techniques, holding times and the analytical method and the analyses to be performed dictate container material requirements. The analytical parameters pertinent to this project, along with the associated analytical methods are listed in Table 2.

7.1.2.6 Sample Identification

Groundwater samples shall be labeled and identified in accordance with applicable procedures (Wehran Engineering, 1990a). Sample labels will be attached to the appropriate sample containers prior to the sampling event.

7.1.2.7 Chain of Custody

Official custody of the samples will be maintained and documented from the time of collection until the time that valid analytical results have been obtained or the laboratory has been released to dispose the samples. Chain of custody (COC) procedures will be conducted in compliance with the appropriate procedures (Wehran Engineering, 1990a).

7.1.2.8 Field Data Documentation

Field descriptions, measurements, and observations will be recorded in a field notebook (Wehran Engineering, 1990a). Minimum information required to accompany all field data include date, time of measurement, name and signature of responsible individual, location and sample number, type of measurement or method name/number, instrument model number, date and time of last calibration, and units of measure. All field data entry sheets shall be signed and dated.

7.1.2.9 Disposition of Wastes

The disposition of purge and decontamination water and waste materials generated during the field purging and sampling will be managed according to existing procedures for the site. Waters generated during this investigation are expected to include only monitoring well purging and sampling water and decontamination water similar to water currently generated under the PMP and will be managed similarly.

7.1.3 Quality Assurance/Quality Control

The quality assurance/quality control (QA/QC) requirements for the groundwater natural remediation project will conform to the requirements established for the PMP (Wehran Engineering, 1990a). As part of the quality assurance (QA) requirements, all personnel performing field activities for the project will have completed minimum training requirements for groundwater sample collection, preservation, and handling, chain-of-custody procedures, equipment decontamination, field measurements, and field chemical analyses.

QA/QC samples will be collected during each sampling event. QA/QC samples include trip blanks, field duplicates and matrix spike duplicates, as appropriate. The analytical results obtained for these samples will be used to assess the quality of the field sampling and laboratory analysis efforts.

7.1.4 Health and Safety

All field activities conducted during this project will be done in compliance with the Site Specific Health and Safety Plan (HASP), CPS Chemical/Madison Industries (Wehran Engineering, 1992). The HASP is incorporated in this

work plan by reference. Personnel responsible for sampling wells are required to read and understand the HASP. Personnel requiring specific health and safety information should consult the HASP.

7.1.5 Analyses

7.1.5.1 Analytical Parameters

Field and laboratory analytical requirements were developed to provide the necessary data to document natural bioactivity associated with degradation of VOCs in the site-related plume. The laboratory and field analytical parameters and analytical methods are listed in Table 3 below.

The monitoring program in support of natural groundwater remediation is divided into two components. The first component is the analysis of VOCs. This will involve quarterly sampling on the same schedule as the quarterly sampling conducted in the PMP. The procedures of sampling and analysis for the VOCs remain the same as they have for the PMP, except that analysis will consist of EPA method 524.2, as indicated previously. The other laboratory and additional field parameters (geochemical parameters) will be sampled three times over the course of the two year project, at the beginning, after one year and at the end of two years, and sampled using the low flow protocol (Appendix A).

Based on the results of the first sampling event, the list of geochemical parameters to be analyzed may be modified. For example, non-detects of a parameter in all project wells will likely result in its exclusion from future sampling events.

The selected analytical parameters fall in three major categories depending on their purpose in documenting naturally occurring bioremediation. A general description of each analyte group is provided below.

- VOCs. These include the contaminants associated with the plume and also some metabolic byproducts (daughter products) of biodegradation of contaminants;
- Analytes for demonstrating microbial activity that might include important microbial nutrients, electron acceptors, electron donors, dissolved gases, or other products of bioactivity; and
- General inorganic water quality parameters necessary to determine basic groundwater chemistry.

Table 3. List of Analytical and Field Parameters

Analyte	Analytical Methods ^a
Alkalinity	E310.1
Ammonia	E350.2/E350.3
Bromide	E300.0
Chloride	E300.0
Dissolved Oxygen	YSI DO Meter No. 54A/E360.1
Magnesium (total dissolved)	E200.7
Manganese (total dissolved)	E200.7
Nitrate	E353.2/E300.0
pH	Orion pH/T Meter No. 230/E150.1
Potassium	E200.7
Sodium	E200.7
Specific Conductance	YSI SC Meter No. 33/E120.1
Sulfate	E300.0
Temperature	Orion pH/T Meter No. 230
Total Dissolved Solids	E160.1
Iron (total dissolved)	E200.7
Total Suspended Solids	E160.2
Volatile organics	524.2
Calcium	E200.7
Carbon Dioxide	4500 CO ₂ ^b /8000 A SW-846
Methane	8015B modified, USEPA SW-846
Ferrous Iron	3500-FE-D ^b
Redox Potential	APHA ^b 2580/ASTM D1498
Total Inorganic Carbon	E9060
Total Organic Carbon	E9060
Notes	
^a U.S. Environmental Protection Agency Methods for Chemical Analysis of Water and Wastes, EPA/600/4-79/020 (1983) unless otherwise noted.	
^b Standard Methods for the Examination of Water and Wastewater, 18th edition (1992).	

Field Parameter Analyses

Parameters selected for field determination were identified on the basis of sensitivity to holding times and/or tendency to be altered by storage for any length of time. In addition, the field parameters were used to determine when sufficient volumes of water had been purged from the monitor well. Parameters specified for field determination include:

- pH
- Specific Conductance
- Temperature
- Oxidation\Reduction (Redox) Potential (E_H or pe)
- Dissolved Oxygen

These parameters are measured at the well head during purging using the in-line flow through cell. The procedure for monitoring well purging is summarized in Section 3.4.3. For VOC samples, collected in the PMP program, field parameters include only temperature, pH and specific conductance. The following sections briefly describe each of these parameters.

pH, Specific Conductance, and Temperature: pH, specific conductance, and temperature will be measured to determine that adequate purging of each well occurs, and that groundwater representative of that in the vicinity of the monitor well is collected for analysis. Specific conductance and pH are important parameters for determining general groundwater quality. Because the pH, temperature, and specific conductance of a groundwater sample can change significantly within a short time following sample acquisition, these parameters must be measured in the field. For this project, measurements will be made in a clean, flow-through chamber when samples are to be collected for geochemical analysis. For VOC analysis the procedures used during the PMP will be followed. The measured values will be recorded in the groundwater sampling records.

The pH of groundwater has an effect on the presence and activity of microbial populations in groundwater. Microbes capable of degrading hydrocarbon compounds generally prefer pH values between six (6) and eight (8) standard pH units, although activities have been observed over a broader pH range. Microbial activity could change the groundwater pH relative to background water quality. For example, by means of the production of organic acids, pH may be lowered in poorly buffered groundwater as a result of microbial activity.

Specific conductance is a measure of the ability of a solution to conduct electricity. Groundwater specific conductance is directly related to the concentration of ions in solution. Stabilized specific conductance measurements are used to demonstrate that the groundwater being sampled is indicative of the groundwater in the aquifer.

Groundwater temperature is another parameter used to determine when sufficient purging has occurred prior to sampling. It also directly affects the solubility of oxygen and other geochemical species. The solubility of dissolved oxygen is temperature dependent, being more soluble in cold water than warm. Groundwater temperature also

affects microbial activity. Rates of hydrocarbon biodegradation approximately double for every 10 degrees centigrade ($^{\circ}\text{C}$) increase in temperature ("Q₁₀ rule") over the range between 5 $^{\circ}\text{C}$ to 25 $^{\circ}\text{C}$. Groundwater temperature less than about 5 $^{\circ}\text{C}$ tends to inhibit biodegradation, and slow rates of biodegradation are generally observed.

Oxidation - Reduction (Redox) Potential: The oxidation-reduction potential (redox potential or ORP) of groundwater is a measure of electron activity, and is an indicator of the tendency of a solution to accept or transfer electrons, relative to a given redox-sensitive species (e.g., Fe^{2+}). The redox potentials (E_{H}) of groundwater typically range from about -400 millivolts (mV) to about +800 mV at neutral pH. Groundwater becomes increasingly anoxic, or anaerobic, as the redox potential decreases.

Redox reactions in groundwater are often biologically mediated, and the redox potential of a groundwater system depends upon and influences the rate of biodegradation. The redox potential of groundwater is important to measure because some biological processes tend to occur within a prescribed range of redox conditions. Also, in hydrocarbon contaminated groundwater, redox potential values tend to decrease as a result of biological activity. The redox potential of groundwater also is a useful indicator of the tendency for certain inorganic geochemical reactions, such as sulfate reduction, to occur.

Because redox potential in groundwater is frequently controlled by microbial activity, redox measurements from a number of wells, including background wells, yield information on the spatial distribution of a contaminant plume as well as identifying areas where biodegradation may be occurring.

Dissolved Oxygen: Dissolved oxygen (DO) is the most thermodynamically-favored electron acceptor used in the biodegradation of aromatic and nonhalogenated aliphatic hydrocarbons and is required for obligate aerobe microbe respiration. The mass of contaminant that can be degraded under aerobic conditions can be estimated based on the DO concentrations. As aerobic biodegradation proceeds, DO concentrations decrease. Chlorinated hydrocarbon degradation occurs in both aerobic and anaerobic environments. Anaerobes (bacteria that require anaerobic conditions) generally cannot function at DO levels greater than about 0.5 mg/L. Because of this restriction, accurate measurements of dissolved oxygen concentrations are important for identifying the important microbial degradation processes.

Techniques used for well purging and sampling influence measured DO concentrations, and therefore, only techniques that create minimal disturbance and aeration of the samples will be used for well purging when samples are collected for the determination of DO and other redox sensitive species. As described in Section 7.1.2, a low-flow pump is recommended for purging and sampling. DO will be monitored using an in-line flow-through cell.

7.1.5.2 Laboratory Analyses

Analytical parameters of this natural groundwater remediation project that are to be analyzed in the laboratory will be determined by a New Jersey certified contract laboratory. Most of the analytes will be analyzed using standard USEPA or APHA methods. However, some analytes, such as dissolved gases, are not routinely analyzed and may require method development by the laboratory. The laboratory analytes and analytical methods are listed in Table 3. The following general groups of analyses will be performed.

- Inorganic water quality parameters and selected metals.
- Volatile organic compounds.
- Carbon (organic and inorganic)
- Dissolved gases.

Inorganic Water Quality Parameters and Metals: The following inorganic water quality parameters and metals will be analyzed by a NJ certified contract laboratory using standard or equivalent laboratory specific protocols, as listed on Table 3. All of the inorganic water quality parameters are components of the geochemical parameter set.

- Nitrate
- Ammonia
- Alkalinity
- Carbon Dioxide
- Total Iron
- Ferrous (Fe^{+2}) Iron
- Manganese
- Calcium
- Magnesium
- Sodium
- Potassium
- Sulfate
- Bromide
- Chloride
- Total dissolved solids

Parameters in this group are necessary to interpret basic groundwater chemistry and to determine the analytical completeness of major ion analyses. These parameters also include critical microbial nutrients and electron acceptors. Several analytes are themselves alternate electron acceptors (eg., sulfate, nitrate) or are indicators of reduction of electron acceptors (eg., ammonia, ferrous iron). The rationale for the inclusion of each of these analytes is discussed below.

Nitrate and Ammonia: Once oxygen is depleted, nitrate, if present, becomes the electrochemically-preferred electron acceptor and the groundwater system becomes anaerobic. Measurements of nitrate in groundwater are required to identify and predict the biodegradation of chlorinated compounds via denitrifying microbes. Nitrite, a product of

denitrification, generally has a short half-life in groundwater and thus was not included as a parameter in this program. Ammonia is an inorganic source of the nutrient, nitrogen, for subsurface microorganisms, as is nitrate.

Alkalinity: Alkalinity is indicative of the capacity of groundwater to neutralize acid and results from the dissolution of geologic materials, the transfer of carbon dioxide (CO_2) from the atmosphere, and the respiration of microorganisms. Alkalinity maintains groundwater pH stability because it provides a buffer against the acids generated during aerobic and anaerobic biological processes. For the purposes of this project, measurements of total alkalinity are useful, in conjunction with carbon dioxide, organic and inorganic carbon measurements, in estimating the degree of mineralization of contaminants and other organic compounds that is occurring. Mineralization refers to the conversion of organic compounds by microorganisms to carbon dioxide, water and inorganic ions. Accurate measurements of alkalinity can be made in the field or laboratory relatively easily.

Carbon Dioxide: Like alkalinity, dissolved carbon dioxide results from the dissolution of geologic materials, the transfer of carbon dioxide from the atmosphere, and the respiration of microorganisms. As indicated above, metabolic processes operating during biodegradation of hydrocarbons leads to the production of carbon dioxide. Significant increase in carbon dioxide within a contaminant plume relative to background concentrations is generally an indicator of active biodegradation. Accurate measurement of CO_2 produced during biodegradation is difficult because carbonate in groundwater (measured as alkalinity) may serve as a source or sink for dissolved CO_2 . If the CO_2 produced during metabolism is not converted to bicarbonate or carbonate in the acid buffering capacity of the aquifer, CO_2 concentrations higher than background may be observed. Measurement of carbon dioxide can provide a useful relative measure of microbiological activity and the occurrence of *in situ* mineralization of contaminants.

Total Iron: Iron is an important component of redox chemistry in many groundwaters. The reduction of ferric to ferrous iron is an important electron transfer process for certain microorganisms under anaerobic conditions. In a site such as Old Bridge, iron bearing minerals are important components of the subsurface, so that iron geochemistry is expected to play an important, if not dominant role in defining the redox conditions in the aquifer. Also, iron minerals in the subsurface at the site may constitute precipitates or sediment in monitor wells. In this case, high total iron measurements may be more indicative of the degree of development of individual wells than they are of the geochemistry of groundwater in the immediate vicinity of the well. For example, it is possible and has been observed that very little dissolved ferrous iron would be measured in some wells where total iron measurements are high. These cases are indicative of aerobic conditions; in conjunction with higher DO levels or redox potential values.

Ferrous Iron: Ferrous iron (Fe^{2+}) concentrations may be indicative of anaerobic degradation of hydrocarbons. During degradation under iron reducing conditions, ferric iron (Fe^{3+}) is used as an electron acceptor and is reduced to the ferrous form. By measuring ferrous iron, the potential for biodegradation of hydrocarbons through ferric iron reduction can be assessed.

Manganese: Manganese can also be a component of the redox chemistry in groundwater. During degradation, manganese can serve as an electron acceptor (similar to ferric iron) for certain microorganisms.

Calcium, Magnesium, Sodium, Potassium, Bromide: All of these constituents are basic inorganic water quality parameters that are useful for interpreting basic groundwater chemistry. They are ions that are frequently important in understanding the geochemical character of the groundwater/aquifer system.

Sulfate: As in the case of nitrate, under anaerobic conditions microorganisms may use sulfate as a terminal electron acceptor. Such sulfate reduction has been related to biodegradation activity, including reductive dehalogenation of multi-chlorinated ethenes or ethanes. Sulfate, where abundant, exerts a strong influence on the geochemistry of groundwater.

Chloride: Under reducing conditions many chlorinated solvents or other chlorinated compounds undergo the process of reductive dehalogenation in groundwater. This process results in the liberation of chloride. Chloride is also liberated when chlorine containing organics are mineralized under aerobic conditions. In some cases, reductive dehalogenation may result in measurable increases in chloride such that a chloride balance would be reflective of reductive dehalogenation. Although at this site it is not expected that the amount of liberated chloride is expected to be significant relative to naturally occurring background chloride levels, chloride measurements are still useful given their importance in describing the geochemistry of the groundwater underlying the site.

7.1.5.3 Organic Water Quality Parameters and Dissolved Gases

A brief discussion of the rationale for the inclusion of these parameters in the program follows.

Volatile Organic Compounds: The volatile organic compound (VOC) analyses include both halogenated and nonhalogenated aliphatic and aromatic hydrocarbons. Table 4 lists the target VOCs for the natural groundwater remediation program, which includes all those associated with the groundwater contaminant plume emanating from the site. This target analyte list includes compounds additional to those reported in the PMP reports. Some of these additional compounds are potential degradation byproducts of parent compounds known to occur in the site-related plume. Also, the individual isomers of xylene and dichloroethene are differentiated in this program, though not in the PMP. Knowing the relative abundance of these isomers provides useful information in interpreting groundwater quality data with respect to natural biodegradation.

The target analytes will be measured by EPA method 524.2. Two compounds on the PMP list, acrolein and 2-chloroethylenevinylether, are not measured by 524.2. However, these compounds have not been associated with the site related plume and are thus not of consequence with respect to the objectives of this work plan. These latter compounds will no longer be reported in the PMP program, as the method change applies to the PMP program as well.

Table 4. Target Analyte List, VOCs

Acetone	1,1-Dichloroethene
Acrylonitrile	cis-1,2-Dichloroethene
Benzene	trans-1,2-Dichloroethene
Bromochloromethane	1,2-Dichloropropane
Bromodichloromethane	cis-1,3-Dichloropropene
Bromoform	trans-1,3-Dichloropropene
Bromomethane	Ethylbenzene
Carbon tetrachloride	Methylene chloride
Chlorobenzene	1,1,1,2-Tetrachloroethane
Chloroethane	1,1,2,2-Tetrachloroethane
Chloroform	Tetrachloroethene
Chloromethane	Toluene
Dibromochloromethane	1,1,1-Trichloroethane
1,2-Dichlorobenzene	1,1,2-Trichloroethane
1,3-Dichlorobenzene	Trichloroethene
1,4-Dichlorobenzene	Vinyl chloride
1,1-Dichloroethane	o-Xylene
1,2-Dichloroethane	m-Xylene
	p-Xylene

Carbon: Carbon analyses include total organic carbon and total inorganic carbon. These analyses are required for understanding the fate of carbon in the aquifer, which includes naturally occurring biodegradation of contaminants. Alkalinity and dissolved carbon dioxide data are also parts of this interpretation process for understanding the fate of carbon in the aquifer. This set of analytes will be determined from samples collected for geochemical analysis.

Methane: Methane is produced under strongly anaerobic conditions by biological activity. The production of methane is a useful indicator of the degree of strongly anaerobic activity in groundwater. Under methanogenic conditions, carbon dioxide is the terminal electron acceptor. The presence of methane is essential for a certain type of aerobic activity, methanotrophy, in which methane is an electron donor and carbon source. Methanotrophic conditions have also been related to certain types of degradation activity. It is anticipated that methane will not be detected in plume groundwater, except possibly near the source. Methane will be analyzed in samples collected for geochemical analysis.

7.2 Data Analysis

7.2.1 Statistical analysis of contaminant concentration data

VOC data in selected monitor wells will be statistically analyzed to determine whether groundwater concentrations are declining over time. This is particularly applicable for those wells located within the plume proper and near the source. The wells for which this statistical analysis will be conducted are listed on Table 5. Recent analyses show measured concentrations of several of the target analytes in these wells above J-values. Thus, the data from these wells are expected to allow a meaningful analysis in determining whether significant concentration changes within the plume are occurring.

The Mann-Whitney U-Test, as described in Appendix C of N.J.A.C. 7:26-E, will be applied to the eight (8) quarters of VOC monitoring data collected pursuant to this work plan. The analytes for which the test will be applied are those generally detected above J-values in recent data, as listed for each well in Table 5. It should be noted that not all of the analytes for which this test will be performed listed on the table occur above the applicable NJGWQ standards. Rather, because the test is performed to determine whether the plume is continuing to remediate naturally, measured, significant decreases in concentration, though the data are below NJGWQ standards, still indicate overall improvements in groundwater quality. It is anticipated that pumping conditions within the aquifer will remain constant over the next two years or so, so such an analysis should be valid for the wells indicated above.

Table 5. Wells and Parameters for Statistical Analysis

Well Number	Analytes for Mann-Whitney U-Test
CPS-3	Acetone, Methylene chloride, 1,2-Dichloroethene, 1,2-Dichloroethane
	Benzene, Toluene, Chlorobenzene, 1,2-Dichlorobenzene, 1,4-Dichlorobenzene, Total xylenes
WE-2R	Acetone, Methylene chloride, 1,2-Dichloroethane,
	Benzene, Toluene, Chlorobenzene, Ethylbenzene
	1,2-Dichlorobenzene, 1,3-Dichlorobenzene, 1,4-Dichlorobenzene, Total Xylenes
CPS-1	1,2-Dichloroethene (total), 1,2-Dichloroethane, Trichloroethene,
	Chlorobenzene, 1,2-Dichlorobenzene, 1,3-Dichlorobenzene, 1,4-Dichlorobenzene
PA-B	Chlorobenzene, 1,2-Dichlorobenzene, 1,4-Dichlorobenzene
WCC-16VS	Chlorobenzene, 1,4-Dichlorobenzene
RW-2	Chlorobenzene

Note that only two of the wells on Table 5, CPS-3 and WE-2R, are area of concern wells. They are the only ones required to demonstrate decrease in concentration pursuant to N.J.A.C. 7:26E-6.3(e), using a statistical test. However, this exercise is expected to provide useful information in interpreting the groundwater monitoring data from the other wells, which are located within the plume along its axis and downgradient from the source. Note that the two area of concern wells are the containment wells for the source area. Data from these pumping wells are considered more representative of groundwater mass flux from the source area than are any of the other available monitor wells in the vicinity.

7.2.2 Interpretation of geochemical data

The geochemical data described in Section 7.1 will be collected to determine whether conditions are consistent with the naturally occurring biodegradation of the plume contaminants. The interpretation of this data is expected to be largely qualitative. It is not expected that changes in geochemical parameters relative to background can be quantitatively related to decreases in concentration of the VOCs in space and time. Rather, this data will be used in a weight-of-evidence approach to determine whether biodegradation is likely to be occurring. For example, the observation that DO concentrations decline downgradient from the source area, if made, would be indicative of aerobic degradation processes.

The geochemical data should allow the development of a conceptual model in which the major types of microbial activity responsible for biodegradation can be determined. For example, zones of aerobic microbial activity could be delineated, as well as zones controlled by the use of other major electron acceptors such as ferric iron or sulfate. Also, relative rates of microbial processes may be determined from a semiquantitative analysis of the data. If the data is of a sufficient quality that consistent spatial and/or temporal trends are recognizable, for example, the use rates of available electron acceptors could be estimated. Little or no change in geochemical parameters such as DO or ferrous iron concentrations, in conjunction with other corroborating data, on the other hand, may indicate that relatively little biological activity is occurring. In this latter case, other processes such as mixing with recharge water or dispersion are responsible for the bulk of the natural groundwater remediation.

7.3 Groundwater Modeling

A groundwater fate and transport model will be used to predict the concentration distribution of benzene in the aquifer in the future. This is to determine whether groundwater concentrations that exceed GWQS would impact the Perth Amboy water supply wells. Model predictions that indicate no such concentration exceedances in the Perth Amboy wells support the applicability of natural groundwater remediation for any portion of the plume that is not currently captured. Predictions would be verified with the groundwater quality data collected in the monitoring portion of this project, as indicated in N.J.A.C. 7:26E-6.3(e).

7.3.1 Model background information

In 1995 (DRAI, 1995) a report was submitted that included a numerical model for predicting future contaminant distribution in the Runyon Wellfield. The model input parameters were based on field testing conducted during several years prior to the submittal of the report, i.e., made use of available data. The results of the modeling effort indicated that recovery well RW-5 had minimal contribution toward aquifer cleanup. Operation of well RW-5 was terminated in July 1995. Since 1995, decreasing VOC concentrations in groundwater have continued, especially in the vicinity of recovery well RW-2.

The model included in the 1995 report will be used in supporting this natural groundwater remediation program. The model code selected is the Method of Characteristics (MOC) model, which is a widely used, public domain model published by the USGS (Konikow and Bredehoeft, 1984). This model couples the groundwater flow equation with the solute transport equation. The digital computer program uses an alternating-direction implicit

procedure to solve the finite difference approximation for the groundwater flow equation and the method of characteristics to solve the solute-transport equation. The model can be used to solve one or two-dimensional problems.

7.3.2 Input parameters

Most basic input parameters to be used in the model will be those used in the 1995 report (DRAI, 1995). Input parameters include groundwater recharge conditions (infiltration rates, surface water bodies), aquifer properties (transmissivity, aquifer thickness, porosity, dispersivity), groundwater pumping rates, transport properties of modeled constituent(s) (retardation coefficient). The input parameters will be reviewed against more recent data and modifications to the parameters will be made as necessary.

Current groundwater pumping conditions will be used in making forward predictions. Differences from the pumping conditions used in the 1995 model include the shut down of RW-5 and RW-2, as well as increased pumping at the former CPS facility and changes in pumping at Madison Industries. Changes in remediation pumping have been detailed in Section 4.4.3 of this work plan. Current Runyon Wellfield pumping conditions will also be used. Other conditions in the model are expected to be the similar to those used in the 1995 model. This includes boundary conditions

One conceptual difference in the model to be used in support of this natural groundwater remediation program as opposed to the 1995 model is the inclusion of a term for biodegradation of the modeled constituent(s). The model will be run with and without biodegradation for comparative purposes. Biodegradation rates will be estimated from the groundwater monitoring data collected pursuant to this program, as well as previous monitoring data. Alternatively, conservative (slow degradation) literature values for biodegradation rates under similar geochemical conditions will be used.

The constituent to be used in the model in support of the groundwater natural remediation project will be benzene. This compound was selected because, in recent PMP groundwater monitoring data, it was the compound that occurred in the highest concentrations relative to its GWQS (1 µg/l), i.e., the ratio of measured concentration to GWQS was typically the highest of the VOCs in wells located within the contaminant plume. Other constituents may be used in addition to benzene, if warranted.

7.3.3 Model calibration

Model calibration procedures will be similar to those used in the DRAI (1995) report. Groundwater flow conditions and the configuration of the benzene concentration distribution will be calibrated. There are now five (5) additional years of available monitoring data with which to calibrate the model, which will be used for that purpose.

7.4 Contingency Plan

In the event that groundwater monitoring data collected pursuant to this work plan or the PMP indicate that groundwater concentrations of one or more monitored VOCs exceed NJ GWQS in two consecutive sampling rounds in one or more sentinel well, well RW-2 will be returned to service, or a well in an appropriate, alternate location

will be installed and put into service. Concentrations exceeding NJ GWQS in RW-2 in two or more consecutive sampling events will also result in a similar action.

If and when either of the conditions indicated above becomes known, NJDEP will be informed. A plan will be submitted within two months following notification detailing the planned actions to remedy the situation, including a schedule of implementation.

7.5 Reporting

Ciba or its consultant will submit two reports describing the results of the natural groundwater remediation work. The first of these is to be a modeling report in which the transport model is described, including calibration, and in which model predictions are made a minimum of five years into the future. Also to be included in this report is information regarding the relevant properties of the contaminants of concern, such as their molecular weight, solubility, tendency to adsorb, biodegradation rates, etc. Preliminary interpretation of the geochemical data from the first round of samples will also be part of this report. This first report will be submitted approximately two months following the first complete sampling round completed pursuant to this investigation. The first sampling round is complete when one event each of sampling for VOCs and for geochemical parameters is complete. For example, if the first round of VOCs and geochemical sampling is completed in December, the first report will be submitted by the end of February of the next year.

The second report will be submitted at the end of the project and will summarize all of the results of the work, including an evaluation of how well the calibrated transport model has predicted groundwater quality in the plume. This second report will be submitted four months following the completion of the last (eighth quarterly) VOCs and (third) geochemical parameter sampling events. This last report will also make recommendations with respect to the future of natural groundwater remediation at the site.

8 SCHEDULE

It is anticipated that this work plan is reviewed and approved in sufficient time to allow the first round of VOCs sampling for the natural groundwater remediation project to occur during the December 1999 PMP monitoring event. The geochemical parameter sampling will be completed soon thereafter, with the first report, the Transport Modeling Report in Support of Natural-Groundwater Remediation, Former CPS Site Plume, Old Bridge, New Jersey (Modeling Report), to be submitted at the end of February (assumes sample completion in December for both VOCs and geochemical parameters). VOCs sampling would proceed quarterly for a total of eight quarterly rounds. Geochemical monitoring will be performed in December 1999, December 2000, and December 2001. The project summary report will be submitted in April 2002.

Should approval of the work plan not be granted in sufficient time for the December 1999 quarterly monitoring event, the first sampling round will be completed in the nearest PMP monitoring event subsequent to approval. The entire schedule will then be extended, with the Modeling Report due two months following the month of the first completed monitoring round, including completion of geochemical sampling. The rest of the schedule would be extended a corresponding amount of time.

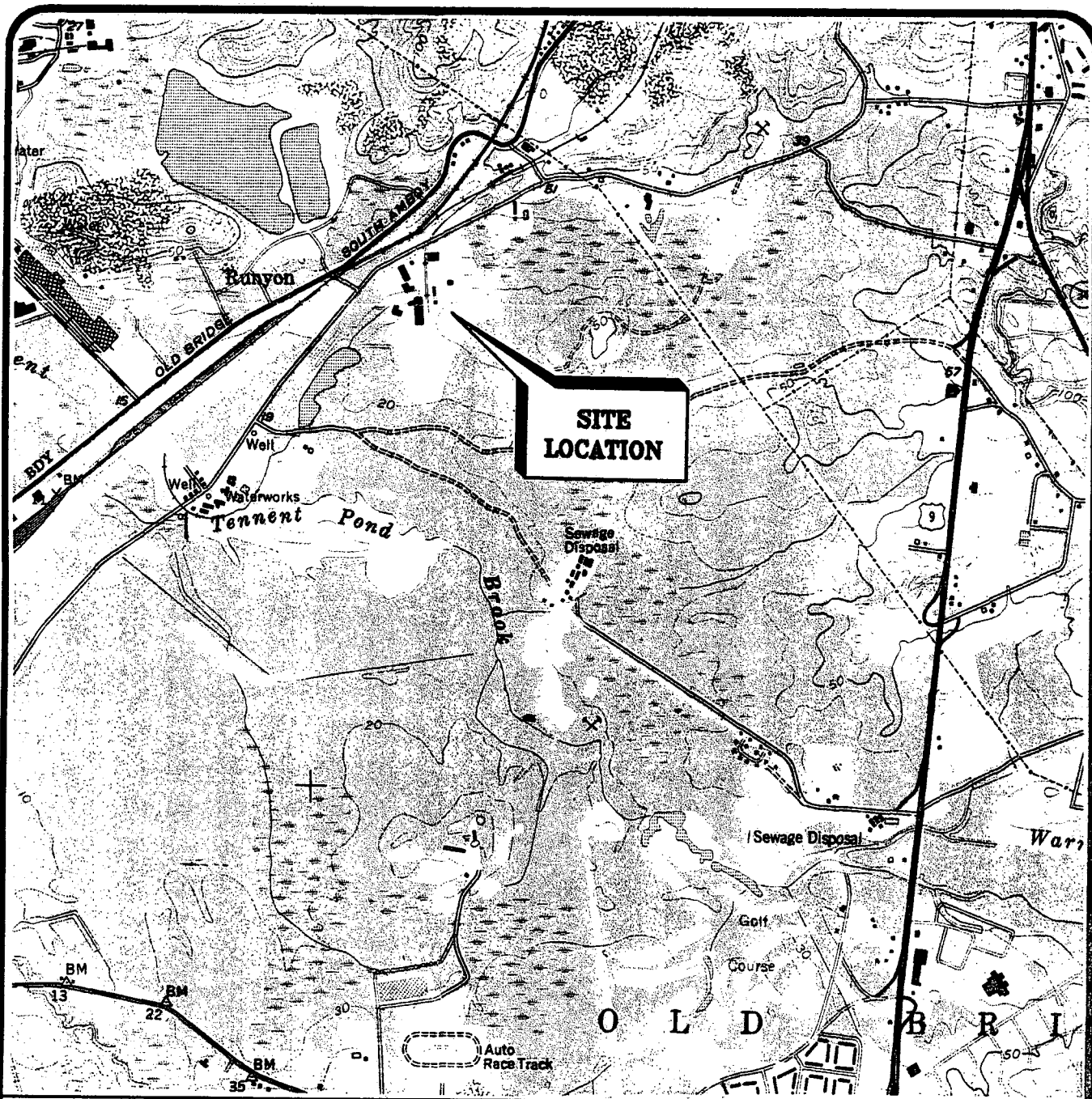
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IMAGE Files: <No Images>

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BASE MAP TAKEN FROM U.S.G.S. 7.5 MIN. QUAD:
SOUTH ANBOY, N.J.- N.Y. DATED 1954, PHOTOREVISED 1981.

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DATE 10/99
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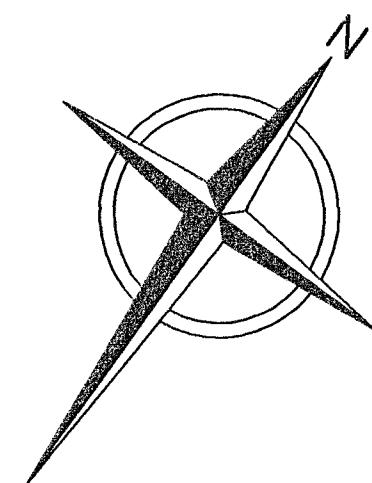
FIGURE 1
CIBA SPECIALTY CHEMICALS CORPORATION
NATURAL REMEDIATION WORK PLAN
MIDDLESEX COUNTY, OLD BRIDGE, N.J.

SITE LOCATION MAP



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SCALE IN FEET

DRAWING NO.
2
PROJECT NO.
706053



PARAMETER	CONCENTRATION
BENZENE	2 J

PARAMETER	CONCENTRATION
1,2-DICHLOROETHANE	3 J
BENZENE	2 J

PARAMETER	CONCENTRATION
VINYL CHLORIDE	25 J
METHYLENE CHLORIDE	240 B
1,2-DICHLOROETHANE (TOTAL)	340
1,2-DICHLOROETHANE	130
TRICHLOROETHENE	27 J
BENZENE	130
TETRACHLOROETHENE	5 JB
1,1,2,2-TETRACHLOROETHANE	32 J
CHLOROBENZENE	890
1,2-DICHLOROBENZENE	1300 B
1,4-DICHLOROBENZENE	240 B

PARAMETER	CONCENTRATION
METHYLENE CHLORIDE	4 JB
1,2-DICHLOROETHANE	29
TRICHLOROETHENE	6
1,1,2,2-TETRACHLOROETHANE	2 J

LEGEND:

- SUPPLY WELL #5 SUPPLY WELL
- RW-5 RECOVERY WELL
- SG-4 STAFF GAUGE
- PIEZOMETER
- MONITORING WELL
- PLUME LINE BASED ON EXCEEDANCE OF MCL

PARAMETER	CONCENTRATION
BENZENE	4 J

PARAMETER	CONCENTRATION
VINYL CHLORIDE	4 J
METHYLENE CHLORIDE	34 B
1,2-DICHLOROETHANE	43
TRICHLOROETHENE	19 J
BENZENE	44
TETRACHLOROETHENE	8J B
1,1,2,2-TETRACHLOROETHANE	24 J
CHLOROBENZENE	580
1,4-DICHLOROBENZENE	170 B

PARAMETER	CONCENTRATION
ALL VOCs	NO EXCEEDANCE OF MCLs

PARAMETER	CONCENTRATION
ALL VOCs	NO EXCEEDANCE OF MCLs

PARAMETER	CONCENTRATION
VINYL CHLORIDE	3 J
1,2-DICHLOROETHANE	20
TRICHLOROETHENE	5
BENZENE	2 J
1,1,2,2-TETRACHLOROETHANE	3 J

PARAMETER	CONCENTRATION
ALL VOCs	NO EXCEEDANCE OF MCLs

PARAMETER	CONCENTRATION
ALL VOCs	NO EXCEEDANCE OF MCLs

PARAMETER	CONCENTRATION
1,1,2,2-TETRACHLOROETHANE	3 J

PARAMETER	CONCENTRATION
ALL VOCs	NO EXCEEDANCE OF MCLs

PARAMETER	CONCENTRATION
ALL VOCs	NO EXCEEDANCE OF MCLs

PARAMETER	CONCENTRATION
1,2-DICHLOROETHANE	4 J
TETRACHLOROETHENE	3 J

PARAMETER	CONCENTRATION
ALL VOCs	NO EXCEEDANCE OF MCLs

PARAMETER	CONCENTRATION
ALL VOCs	NO EXCEEDANCE OF MCLs

PARAMETER	CONCENTRATION
ALL VOCs	NO EXCEEDANCE OF MCLs

PARAMETER	CONCENTRATION
ALL VOCs	NO EXCEEDANCE OF MCLs

NOTES:

PARAMETER	MCL CONCENTRATION
METHYLENE CHLORIDE	3
VINYL CHLORIDE	2
1,1-DICHLOROETHENE	2
1,1-DICHLOROETHANE	50
1,2-DICHLOROETHENE (TOTAL)	(70-100)
1,2-DICHLOROETHANE	2
TRICHLOROETHENE	1
BENZENE	1
TETRACHLOROETHENE	1
1,1,2,2-TETRACHLOROETHANE	1
CHLOROBENZENE	50
1,2-DICHLOROBENZENE	600
1,4-DICHLOROBENZENE	75

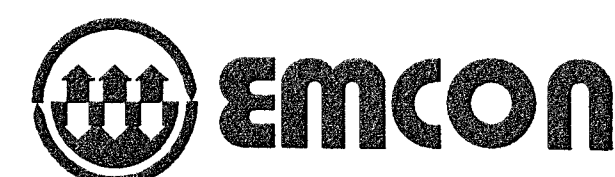
MCL = MAXIMUM CONTAMINANT LEVEL

B = ANALYTE FOUND IN BLANKS AS WELL AS SAMPLES

J = ANALYTE IS PRESENT BUT AT A CONCENTRATION LESS THAN DETECTION LIMIT

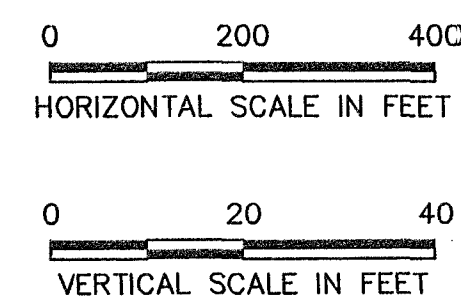
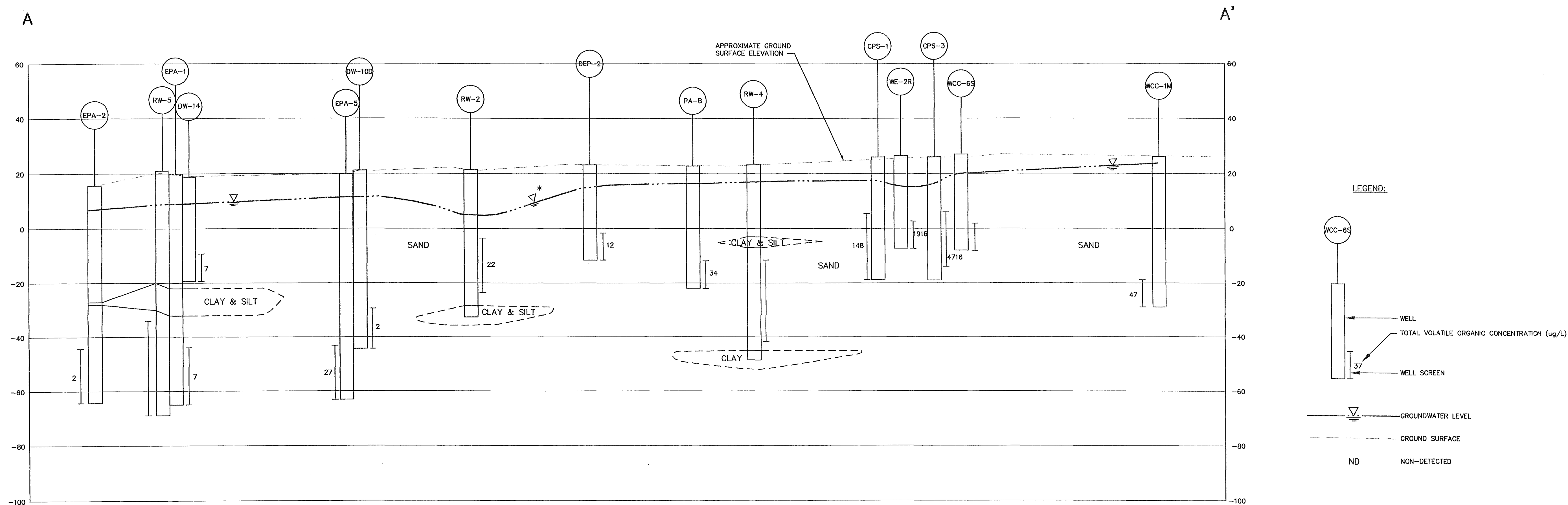
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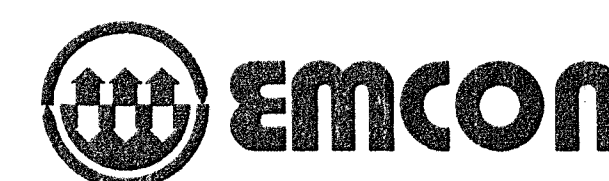
CIBA SPECIALTY CHEMICALS CORPORATION
NATURAL REMEDIATION WORK PLAN
MIDDLESEX COUNTY, OLD BRIDGE, NEW JERSEY
**PLUME OF VOLATILE ORGANICS
BASED ON EXCEEDANCE OF MCLs**
JUNE 1999

DRAWING NO.
3
PROJECT NO.
796053



* DRAWDOWN AT RECOVERY WELL INFERRED

REV	DATE	DESCRIPTION	DWN BY	DES BY	CHK BY	APP BY
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CIBA SPECIALTY CHEMICALS CORPORATION
NATURAL REMEDIATION WORK PLAN
MIDDLESEX COUNTY, OLD BRIDGE, NEW JERSEY
CROSS SECTION A-A'
REVISED
(JUNE 1999)

DRAWING NO.
5
PROJECT NO.
726053

**APPENDIX A: U.S. ENVIRONMENTAL PROTECTION AGENCY REGION II GROUND WATER
SAMPLING PROCEDURE, LOW STRESS (Low Flow) PURGING AND SAMPLING**

U.S. ENVIRONMENTAL PROTECTION AGENCY
REGION II

GROUND WATER SAMPLING PROCEDURE
LOW STRESS (Low Flow) PURGING AND SAMPLING

I. SCOPE & APPLICATION

This Low Stress (or Low-Flow) Purging and Sampling Procedure is the EPA Region II standard method for collecting low stress (low flow) ground water samples from monitoring wells. Low stress Purging and Sampling results in collection of ground water samples from monitoring wells that are representative of ground water conditions in the geological formation. This is accomplished by minimizing stress on the geological formation and minimizing disturbance of sediment that has collected in the well. The procedure applies to monitoring wells that have an inner casing with a diameter of 2.0 inches or greater, and maximum screened intervals of ten feet unless multiple intervals are sampled. The procedure is appropriate for collection of ground water samples that will be analyzed for volatile and semi-volatile organic compounds (VOCs and SVOCs), pesticides, polychlorinated biphenyls (PCBs), metals, and microbiological and other contaminants in association with all EPA programs.

This procedure does not address the collection of light or dense non-aqueous phase liquids (LNAPL or DNAPL) samples, and should be used for aqueous samples only. For sampling NAPLs, the reader is referred to the following EPA publications: DNAPL Site Evaluation (Cohen & Mercer, 1993) and the RCRA Ground-Water Monitoring: Draft Technical Guidance (EPA/530-R-93-001), and references therein.

II. METHOD SUMMARY

The purpose of the low stress purging and sampling procedure is to collect ground water samples from monitoring wells that are representative of ground water conditions in the geological formation. This is accomplished by setting the intake velocity of the sampling pump to a flow rate that limits drawdown inside the well casing.

Sampling at the prescribed (low) flow rate has three primary benefits. First, it minimizes disturbance of sediment in the bottom of the well, thereby producing a sample with low turbidity (i.e., low concentration of suspended particles). Typically, this saves time and analytical costs by eliminating the need for collecting and analyzing an additional filtered sample from the same well. Second, this procedure minimizes aeration of the ground water during sample collection, which improves the sample quality for VOC analysis. Third, in most cases the procedure significantly reduces the volume of ground water purged from a well and the costs associated with its proper treatment and disposal.

III. ADDRESSING POTENTIAL PROBLEMS

Problems that may be encountered using this technique include a) difficulty in sampling wells with insufficient yield; b) failure of one or more key indicator parameters to stabilize; c) cascading of water and/or formation of air bubbles in the tubing; and d) cross-contamination between wells.

Insufficient Yield

Wells with insufficient yield (i.e., low recharge rate of the well) may dewater during purging. Care should be taken to avoid loss of pressure in the tubing line due to dewatering of the well below the level of the

pump's intake. Purging should be interrupted before the water level in the well drops below the top of the pump, as this may induce cascading of the sand pack. Pumping the well dry should therefore be avoided to the extent possible in all cases. Sampling should commence as soon as the volume in the well has recovered sufficiently to allow collection of samples. Alternatively, ground water samples may be obtained with techniques designed for the unsaturated zone, such as lysimeters.

Failure to Stabilize Key Indicator Parameters

If one or more key indicator parameters fails to stabilize after 4 hours, one of three options should be considered: a) continue purging in an attempt to achieve stabilization; b) discontinue purging, do not collect samples, and document attempts to reach stabilization in the log book; c) discontinue purging, collect samples, and document attempts to reach stabilization in the log book; or d) Secure the well, purge and collect samples the next day (preferred). The key indicator parameter for samples to be analyzed for VOCs is dissolved oxygen. The key indicator parameter for all other samples is turbidity.

Cascading

To prevent cascading and/or air bubble formation in the tubing, care should be taken to ensure that the flow rate is sufficient to maintain pump suction. Minimize the length and diameter of tubing (i.e., 1/4 or 3/8 inch ID) to ensure that the tubing remains filled with ground water during sampling.

Cross-Contamination

To prevent cross-contamination between wells, it is strongly recommended that dedicated, in-place pumps be used. As an alternative, the potential for cross-contamination can be reduced by performing the more thorough "daily" decontamination procedures between sampling of each well in addition to the start of each sampling day (see Section VII, below).

Equipment Failure

Adequate equipment should be on-hand so that equipment failures do not adversely impact sampling activities.

IV. PLANNING DOCUMENTATION AND EQUIPMENT

- Approved site-specific Field Sampling Plan/Quality Assurance Project Plan (QAPP). This plan must specify the type of pump and other equipment to be used. The QAPP must also specify the depth to which the pump intake should be lowered in each well. Generally, the target depth will correspond to the mid-point of the most permeable zone in the screened interval. Borehole geologic and geophysical logs can be used to help select the most permeable zone. However, in some cases, other criteria may be used to select the target depth for the pump intake. In all cases, the target depth must be approved by the EPA hydrogeologist or EPA project scientist.
- Well construction data, location map, field data from last sampling event.
- Polyethylene sheeting.
- Flame Ionization Detector (FID) and Photo Ionization Detector (PID).

- Adjustable rate, positive displacement ground water sampling pump (e.g., centrifugal or bladder pumps constructed of stainless steel or Teflon). A peristaltic pump may only be used for inorganic sample collection.
- Interface probe or equivalent device for determining the presence or absence of NAPL.
- Teflon or Teflon-lined polyethylene tubing to collect samples for organic analysis. Teflon or Teflon-lined polyethylene, PVC, Tygon or polyethylene tubing to collect samples for inorganic analysis. Sufficient tubing of the appropriate material must be available so that each well has dedicated tubing.
- Water level measuring device, minimum 0.01 foot accuracy, (electronic preferred for tracking water level drawdown during all pumping operations).
- Flow measurement supplies (e.g., graduated cylinder and stop watch or in-line flow meter).
- Power source (generator, nitrogen tank, etc.).
- Monitoring instruments for indicator parameters. Eh and dissolved oxygen must be monitored in-line using an instrument with a continuous readout display. Specific conductance, pH, and temperature may be monitored either in-line or using separate probes. A nephelometer is used to measure turbidity.
- Decontamination supplies (see Section VII, below).
- Logbook (see Section VIII, below).
- Sample bottles.
- Sample preservation supplies (as required by the analytical methods).
- Sample tags or labels, chain of custody.

V. SAMPLING PROCEDURES

Pre-Sampling Activities

1. Start at the well known or believed to have the least contaminated ground water and proceed systematically to the well with the most contaminated ground water. Check the well, the lock, and the locking cap for damage or evidence of tampering. Record observations.
2. Lay out sheet of polyethylene for placement of monitoring and sampling equipment.
3. Measure VOCs at the rim of the unopened well with a PID and FID instrument and record the reading in the field log book.
4. Remove well cap.
5. Measure VOCs at the rim of the opened well with a PID and an FID instrument and record the reading in the field log book.

6. If the well casing does not have a reference point (usually a V-cut or indelible mark in the well casing), make one. Note that the reference point should be surveyed for correction of ground water elevations to the mean geodesic datum (MSL).
7. Measure and record the depth to water (to 0.01 ft) in all wells to be sampled prior to purging. Care should be taken to minimize disturbance in the water column and dislodging of any particulate matter attached to the sides or settled at the bottom of the well.
8. If desired, measure and record the depth of any NAPLs using an interface probe. Care should be taken to minimize disturbance of any sediment that has accumulated at the bottom of the well. Record the observations in the log book. If LNAPLs and/or DNAPLs are detected, install the pump at this time, as described in step 9, below. Allow the well to sit for several days between the measurement or sampling of any DNAPLs and the low-stress purging and sampling of the ground water.

Sampling Procedures

9. **Install Pump:** Slowly lower the pump, safety cable, tubing and electrical lines into the well to the depth specified for that well in the EPA-approved QAPP or a depth otherwise approved by the EPA hydrogeologist or EPA project scientist. The pump intake must be kept at least two (2) feet above the bottom of the well to prevent disturbance and resuspension of any sediment or NAPL present in the bottom of the well. Record the depth to which the pump is lowered.
10. **Measure Water Level:** Before starting the pump, measure the water level again with the pump in the well. Leave the water level measuring device in the well.
11. **Purge Well:** Start pumping the well at 200 to 500 milliliters per minute (ml/min). The water level should be monitored approximately every five minutes. Ideally, a steady flow rate should be maintained that results in a stabilized water level (drawdown of 0.3 ft or less). Pumping rates should, if needed, be reduced to the minimum capabilities of the pump to ensure stabilization of the water level. As noted above, care should be taken to maintain pump suction and to avoid entrainment of air in the tubing. Record each adjustment made to the pumping rate and the water level measured immediately after each adjustment.
12. **Monitor Indicator Parameters:** During purging of the well, monitor and record the field indicator parameters (turbidity, temperature, specific conductance, pH, Eh, and DO) approximately every five minutes. The well is considered stabilized and ready for sample collection when the indicator parameters have stabilized for three consecutive readings as follows (Puls and Barcelona, 1996):

± 0.1 for pH
 $\pm 3\%$ for specific conductance (conductivity)
 ± 10 mv for redox potential
 $\pm 10\%$ for DO and turbidity

Dissolved oxygen and turbidity usually require the longest time to achieve stabilization. The pump must not be removed from the well between purging and sampling.

13. **Collect Samples:** Collect samples at a flow rate between 100 and 250 ml/min and such that drawdown of the water level within the well does not exceed the maximum allowable drawdown

of 0.3 ft. VOC samples must be collected first and directly into sample containers. All sample containers should be filled with minimal turbulence by allowing the ground water to flow from the tubing gently down the inside of the container.

Ground water samples to be analyzed for volatile organic compounds (VOCs) require pH adjustment. The appropriate EPA Program Guidance should be consulted to determine whether pH adjustment is necessary. If pH adjustment is necessary for VOC sample preservation, the amount of acid to be added to each sample vial prior to sampling should be determined, drop by drop, on a separate and equal volume of water (e.g., 40 ml). Ground water purged from the well prior to sampling can be used for this purpose.

14. Remove Pump and Tubing: After collection of the samples, the tubing, unless permanently installed, must be properly discarded or dedicated to the well for resampling by hanging the tubing inside the well.
15. Measure and record well depth.
16. Close and lock the well.

VI. FIELD QUALITY CONTROL SAMPLES

Quality control samples must be collected to determine if sample collection and handling procedures have adversely affected the quality of the ground water samples. The appropriate EPA Program Guidance should be consulted in preparing the field QC sample requirements of the site-specific QAPP.

All field quality control samples must be prepared exactly as regular investigation samples with regard to sample volume, containers, and preservation. The following quality control samples should be collected during the sampling event:

- Field duplicates
- Trip blanks for VOCs only
- Equipment blank (not necessary if equipment is dedicated to the well)

As noted above, ground water samples should be collected systematically from wells with the lowest level of contamination through to wells with highest level of contamination. The equipment blank should be collected after sampling from the most contaminated well.

VII. DECONTAMINATION

Non-disposable sampling equipment, including the pump and support cable and electrical wires which contact the sample, must be decontaminated thoroughly each day before use ("daily decon") and after each well is sampled ("between-well decon"). Dedicated, in-place pumps and tubing must be thoroughly decontaminated using "daily decon" procedures (see #17, below) prior to their initial use. For centrifugal pumps, it is strongly recommended that non-disposable sampling equipment, including the pump and support cable and electrical wires in contact with the sample, be decontaminated thoroughly each day before use ("daily decon").

EPA's field experience indicates that the life of centrifugal pumps may be extended by removing entrained grit. This also permits inspection and replacement of the cooling water in centrifugal pumps. All

non-dedicated sampling equipment (pumps, tubing, etc.) must be decontaminated after each well is sampled ("between-well decon," see #18 below).

17. **Daily Decon**

A) Pre-rinse: Operate pump in a deep basin containing 8 to 10 gallons of potable water for 5 minutes and flush other equipment with potable water for 5 minutes.

B) Wash: Operate pump in a deep basin containing 8 to 10 gallons of a non-phosphate detergent solution, such as Alconox, for 5 minutes and flush other equipment with fresh detergent solution for 5 minutes. Use the detergent sparingly.

C) Rinse: Operate pump in a deep basin of potable water for 5 minutes and flush other equipment with potable water for 5 minutes.

D) Disassemble pump.

E) Wash pump parts: Place the disassembled parts of the pump into a deep basin containing 8 to 10 gallons of non-phosphate detergent solution. Scrub all pump parts with a test tube brush.

F) Rinse pump parts with potable water.

G) Rinse the following pump parts with distilled/ deionized water: inlet screen, the shaft, the suction interconnector, the motor lead assembly, and the stator housing.

H) Place impeller assembly in a large glass beaker and rinse with 1% nitric acid (HNO_3).

I) Rinse impeller assembly with potable water.

J) Place impeller assembly in a large glass beaker and rinse with isopropanol.

K) Rinse impeller assembly with distilled/deionized water.

18. **Between-Well Decon**

A) Pre-rinse: Operate pump in a deep basin containing 8 to 10 gallons of potable water for 5 minutes and flush other equipment with potable water for 5 minutes.

B) Wash: Operate pump in a deep basin containing 8 to 10 gallons of a non-phosphate detergent solution, such as Alconox, for 5 minutes and flush other equipment with fresh detergent solution for 5 minutes. Use the detergent sparingly.

C) Rinse: Operate pump in a deep basin of potable water for 5 minutes and flush other equipment with potable water for 5 minutes.

D) Final Rinse: Operate pump in a deep basin of distilled/deionized water to pump out 1 to 2 gallons of this final rinse water.

VIII. FIELD LOG BOOK

A field log book must be kept each time ground water monitoring activities are conducted in the field. The field log book should document the following:

- Well identification number and physical condition.
- Well depth, and measurement technique.
- Static water level depth, date, time, and measurement technique.
- Presence and thickness of immiscible liquid layers and detection method.
- Collection method for immiscible liquid layers.
- Pumping rate, drawdown, indicator parameters values, and clock time, at three to five minute intervals; calculate or measure total volume pumped.
- Well sampling sequence and time of sample collection.
- Types of sample bottles used and sample identification numbers.
- Preservatives used.
- Parameters requested for analysis.
- Field observations of sampling event.
- Name of sample collector(s).
- Weather conditions.
- QA/QC data for field instruments.

IX. REFERENCES

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